



# **Radiometric and Geometric Assessment of CBERS-2B, SPOT-5, and RapidEye**

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U.S. Department of the Interior

U.S. Geological Survey

# Outline

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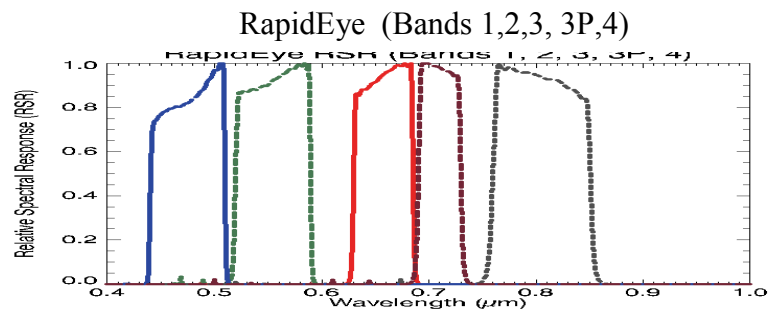
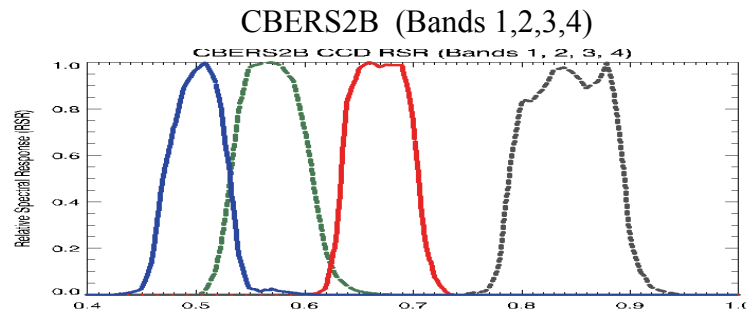
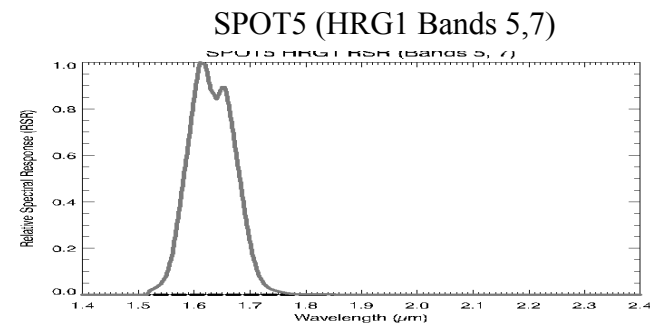
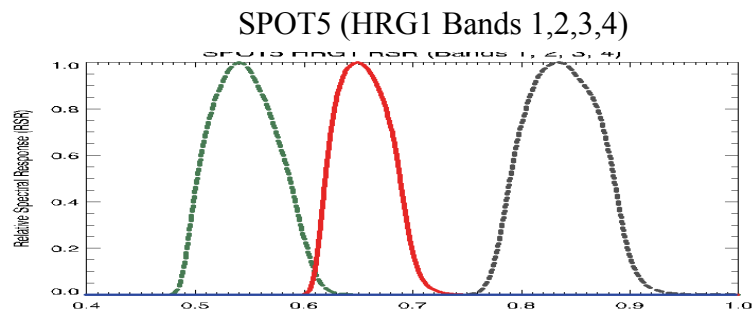
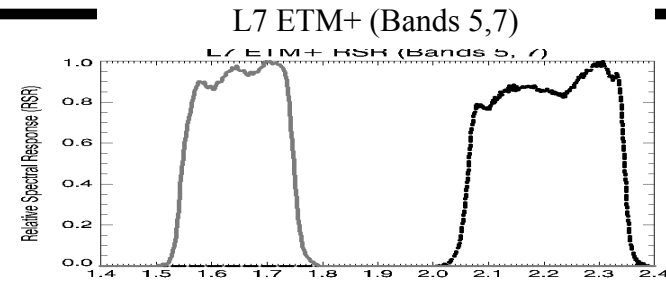
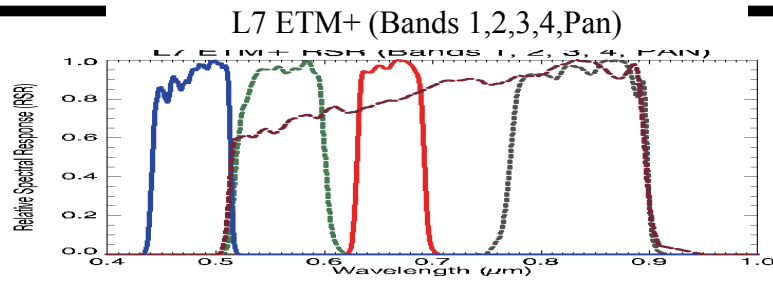
- **RSR Profiles comparison**
- **Sensor Overview**
- **Radiometric Assessment**
- **Geometric Assessment**
- **Summary**

# **Radiometric Assessment**

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- **Consists of comparing RSR Profiles**
- **Qualitative Analysis of each sensor**
- **Work started on the assessment using Pseudo Invariant Calibration Sites (PICS)**

# Relative Spectral Response (RSR) Profiles





# Geometric Assessment

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- **Completed using the Image Assessment System (IAS) which was developed for Radiometric and Geometric Characterization and Calibration for The Landsat program.**
- **Band to Band (B2B) registration assessment tool**
  - ◆ B2B is performed to ensure that the proper band alignment parameters are provided
  - ◆ It is typically done by registering each band against every other band
  - ◆ A reference band is selected and all other bands are adjusted (offset determined) by least square adjustment of the registration solution
- **Image to Image (I2I) registration assessment tool**
  - ◆ I2I is usually performed to compare the relative accuracy between two images
  - ◆ One image is selected as reference and another as the search image
  - ◆ Image chips are selected from reference image and are correlated with search image
  - ◆ The co-registration results provide an insight to the relative accuracy of the search image with respect to the reference image
  - ◆ When the correlated points are plotted in the image, it also helps to detect any systematic bias in the image



# Geometric Assessment

SENSOR	Processing Levels*	Analysis Performed
CBERS-2B	Level 2 standard product (systematic correction)	Band to Band (B1 – B4, excluded pan band) Image to Image (Control : DOQ)
SPOT 5	Level 2A (systematic correction)	Band to Band (B1 – B4, pan band unavailable) Image to Image (Control : DOQ)
RapidEye–3	Level 3A (precision & terrain correction)	Band to Band (B1 – B5) Image to Image (Control : DOQ, Landsat L1T)

# CBERS-2B Sensor Overview

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- Same bus as CBERS-2
- Three onboard cameras (CCD, WFI, HRC)
  - ◆ CCD and WFI cameras are the same as in CBERS-2
  - ◆ CCD: 20 m
  - ◆ WFI: 258 m
  - ◆ HRC: 2.5 m
  - ◆ No IRMSS sensor

# CBERS Downlink at USGS

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- CBERS-2 test downlink was successfully performed at the USGS EROS Center on March 26-April 02, 2006
- CBERS-2B test downlink was successfully performed on Nov 24-28, 2008

## Acquisition

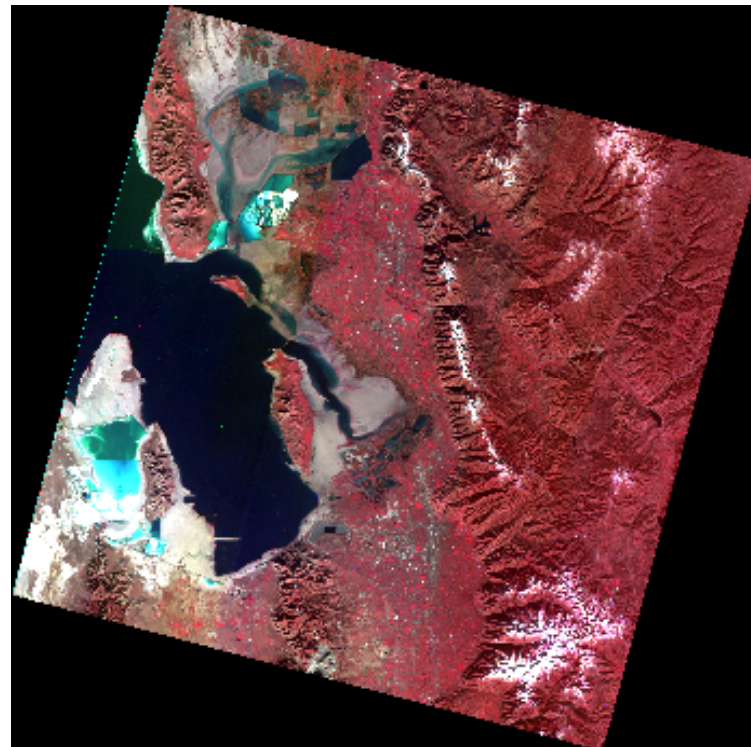
Date: Nov 25, 2008

Path: 238

Row: 054

Salt Lake City, Utah

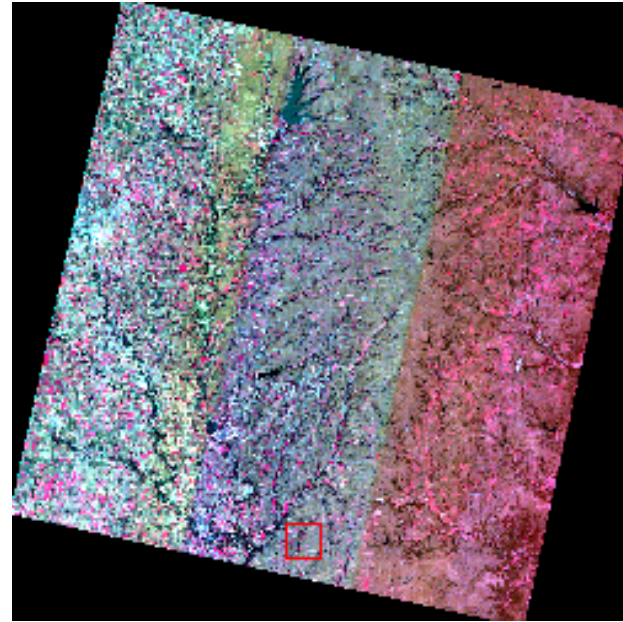
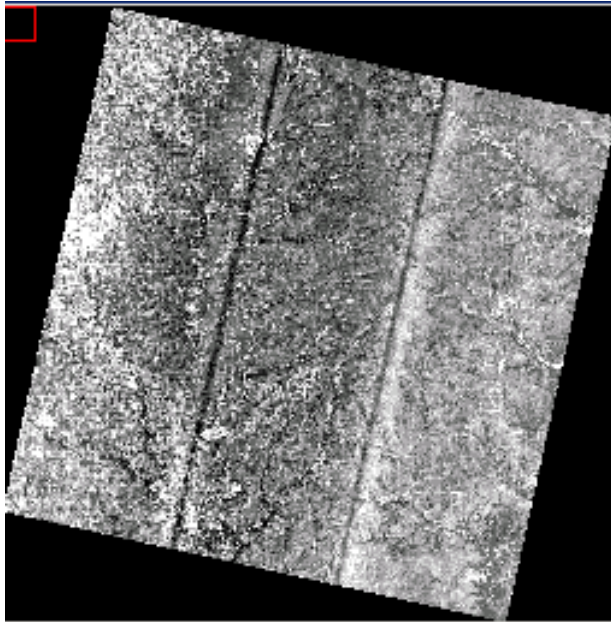
CB2BCCD23805420081125



# CBERS-2B (QA/QC)

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- Quick look assessments revealed artifacts including striping, noise, and saturation of detectors
  - ◆ Example of the discontinuities between the three CCD arrays overlay

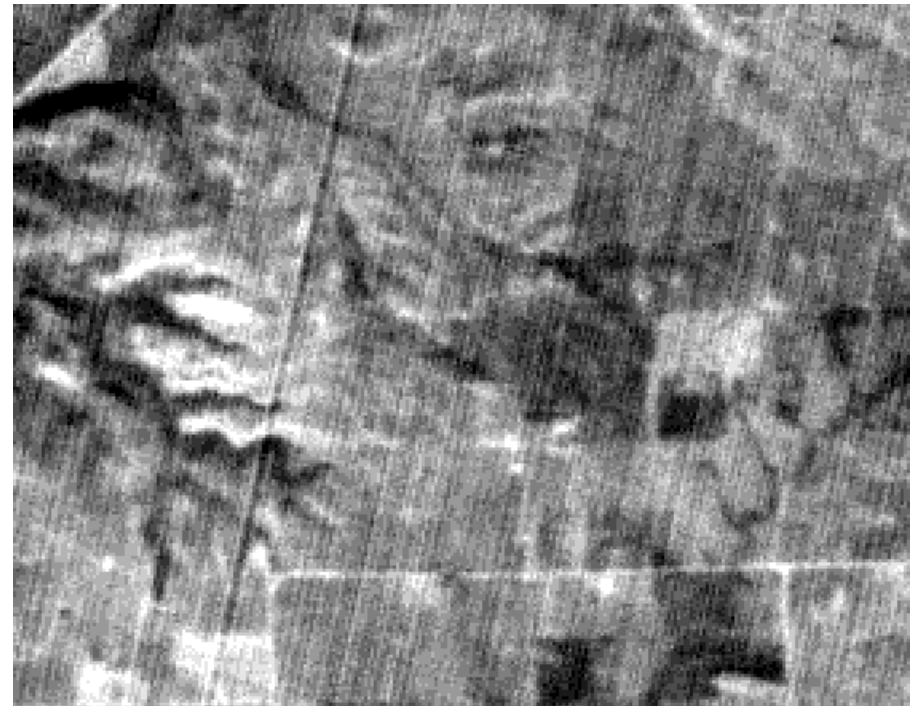
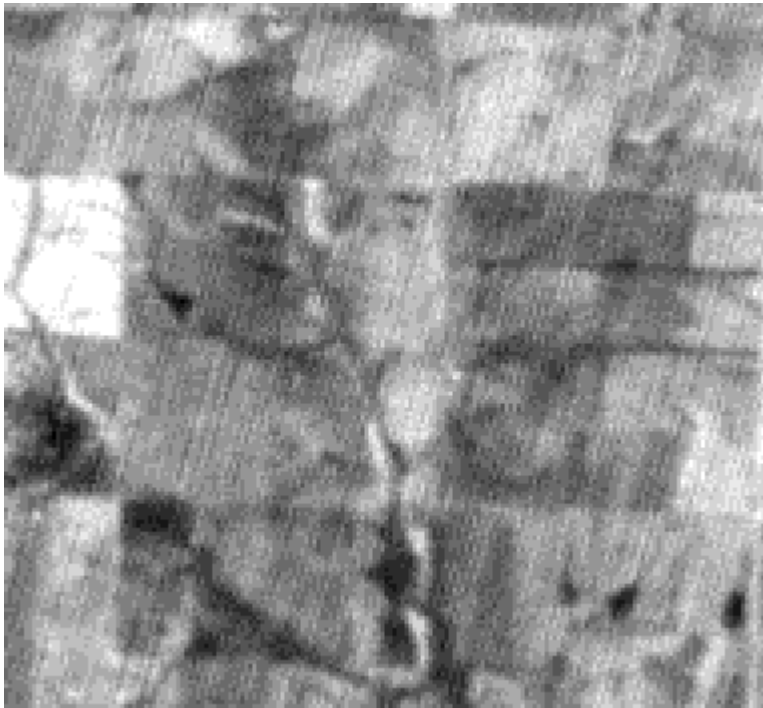




# CBERS-2B (QA/QC)

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- ◆ Striping is evident throughout imagery



# CBERS-2B (I2I)

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- **The Level 2 CBERS product could not be directly used by the I2I tool in IAS to derive Image to Image statistics**
  - ◆ DOQ with an accuracy of ~6 m is resampled to 20 m to match the resolution of the CBERS-2B pan band
  - ◆ ENVI was used to visually identify points between DOQ and CBERS data, which are then refined by grey scale correlation
- **Comparing with DOQ, the CBERS-2B data showed a mean of 3024 m in the line direction and 1778 m in the sample direction**

# CBERS-2B (I2I)

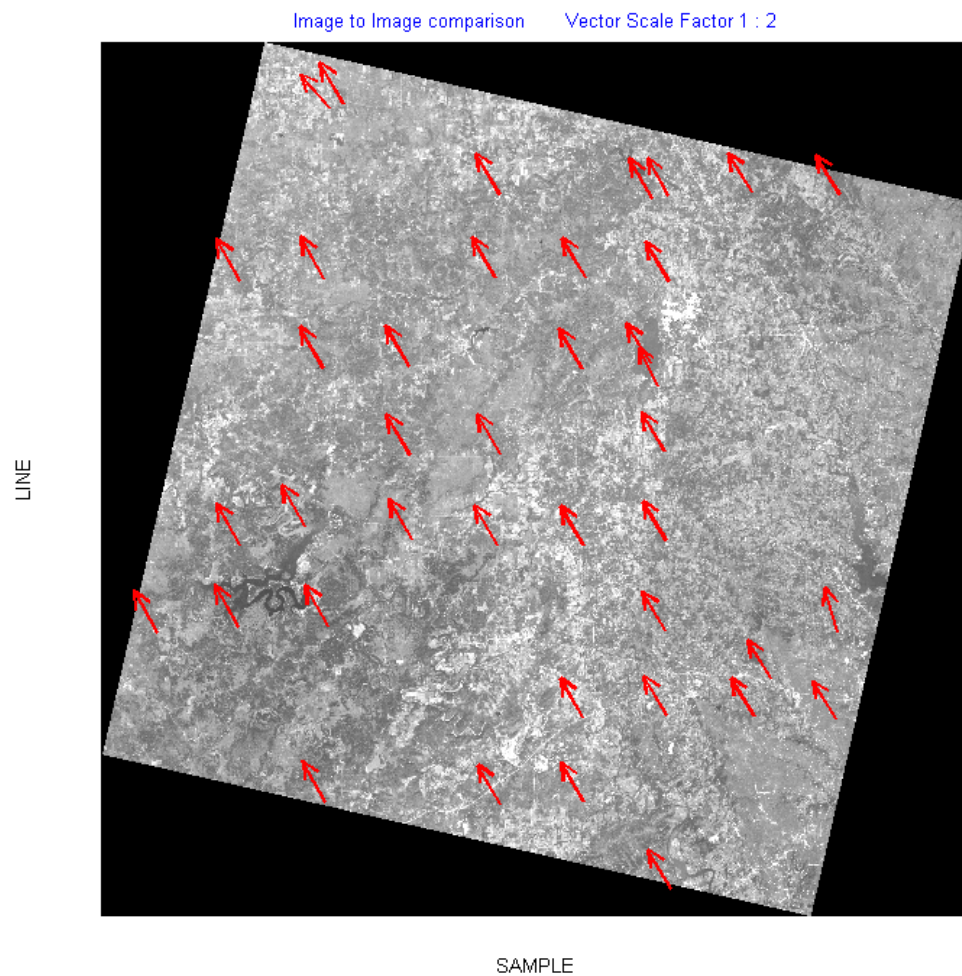
- The relative image accuracy of DOQ and CBERS-2B showed about 3500m RMSEr
  - ◆ There is significant bias in the product
  - ◆ High standard deviation shows that there may be problems in correcting the CCD arrays

40 points used to calculate statistics	Pixels		Meters	
	Line	Sample	Line	Sample
Mean	-151.2	-88.9	-3024	-1778
Standard Deviation	6.8	8.1	136	162
RMSE	151.3	89.2	3026	1784



# CBERS 2B (I2I) Vector scale 1:2

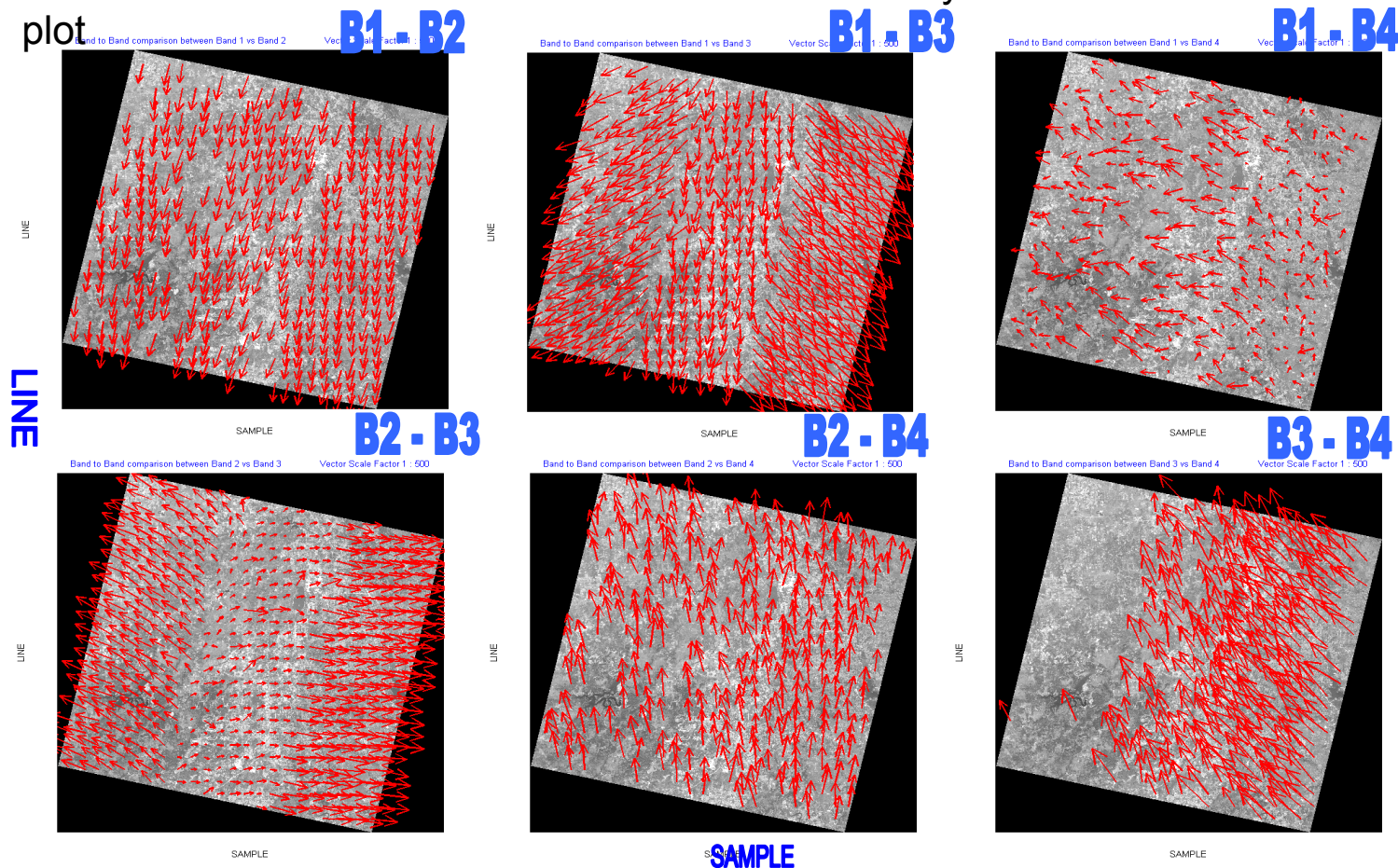
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# CBERS-2B (B2B) Vector Scale 1:500

The multi-spectral bands are registered to about 1 pixel accuracy

Band 3 shows some issues with individual CCD array correction as evident in the B2B plot



# SPOT-5 Overview

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- **SPOT 5 was launched in mid 2002**
  - ◆ Improved resolution -- 2.5m (and 5m) (Not Assessed)
  - ◆ 10m Multispectral
  - ◆ Dedicated Stereo-imager – global strip mapping
  - ◆ Vegetation instrument – 4 band 1km daily global coverage
- **60 x 60 km scene size**

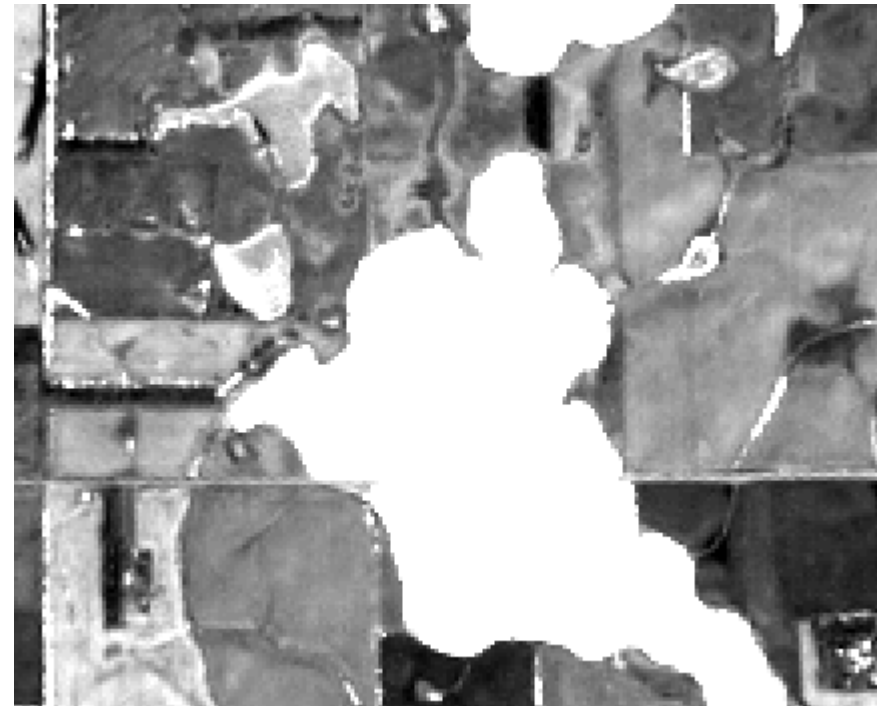


# SPOT-5 QA/QC

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**B4 Ringing**



**B1, 2, 3 Saturation**



# SPOT-5 (I2I)

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- DOQ (resolution 1 m) with an accuracy of ~6 m is resampled to 10 m to match the resolution of the SPOT-5 multi-spectral bands
- Since Pan band is unavailable for the scene, SPOT-5 B3 data is used for image to image accuracy with DOQ
- Comparing with DOQ, the SPOT data showed a mean of 14.3 m in the line direction and 17.2 m in the sample direction
- Small systematic effects are observed in the product

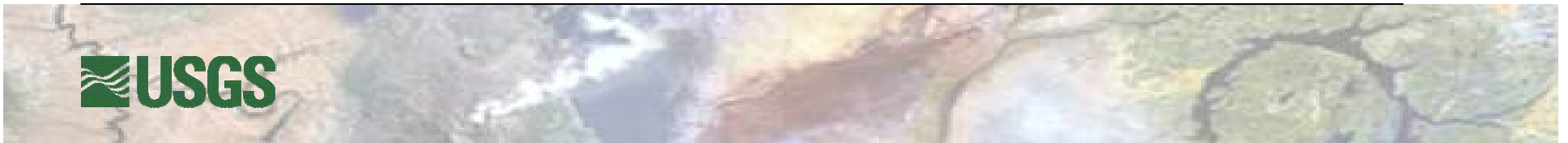


# SPOT-5 (I2I)

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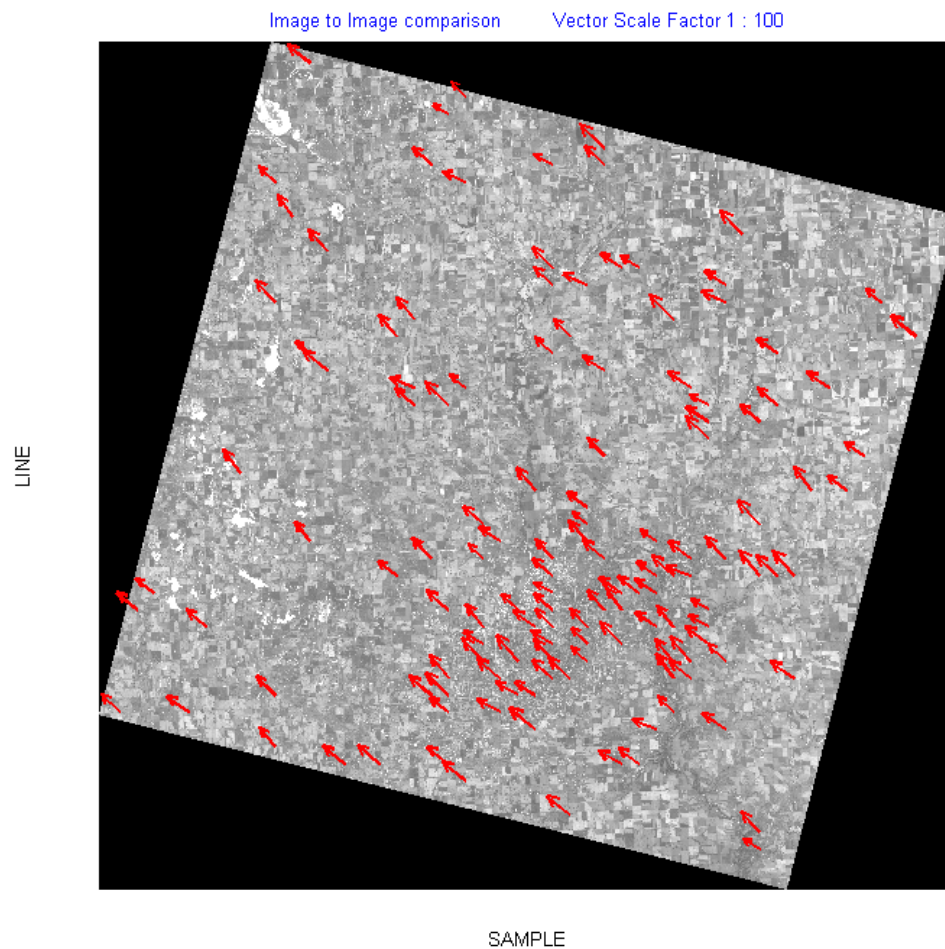
- The relative image accuracy of DOQ and SPOT showed 22.7 m RMSEr
- This result is very good given that the SPOT data is not precision and terrain corrected

132 points used to calculate statistics	Pixels		Meters	
	Line	Sample	Line	Sample
Mean	-1.43	-1.72	-14.3	-17.2
Standard Deviation	0.36	0.24	3.6	2.4
RMSE	1.48	1.73	14.8	17.3



# SPOT-5 (I2I) Vector scale 1:100

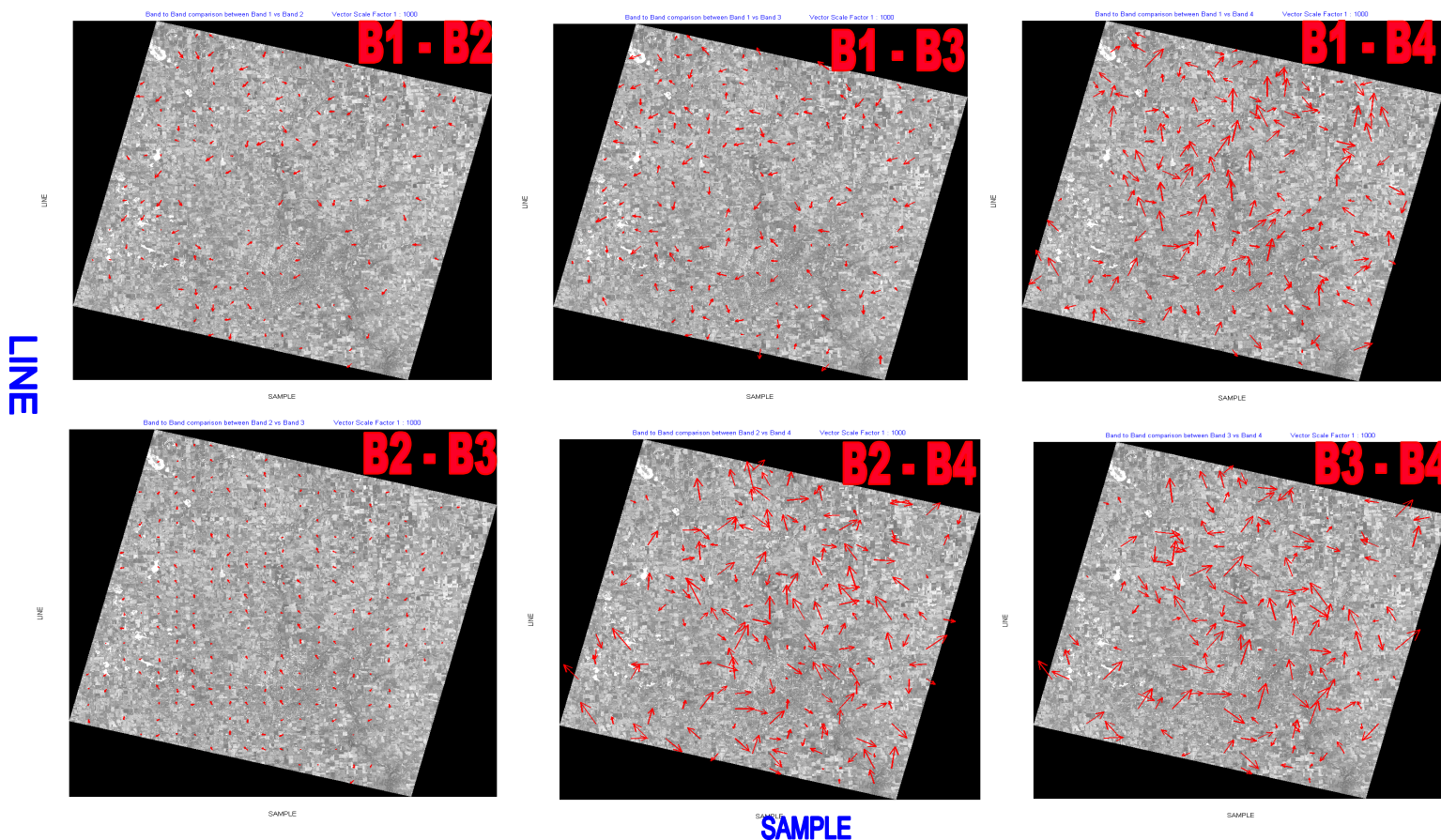
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# SPOT-5 (B2B) Vector Scale 1:1000

The multi-spectral bands are registered to sub-pixel accuracy

Band 4 is about quarter of a pixel off (2.5 m) from the rest of the bands

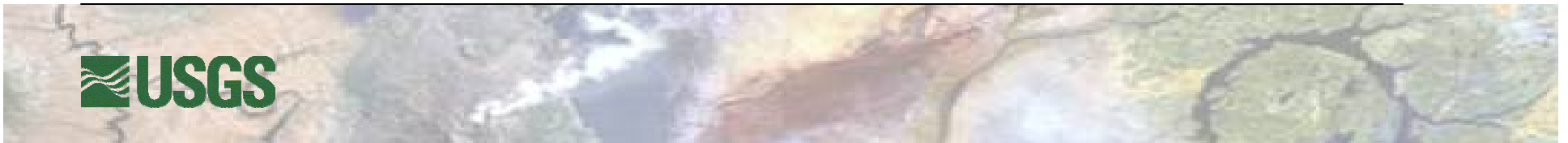
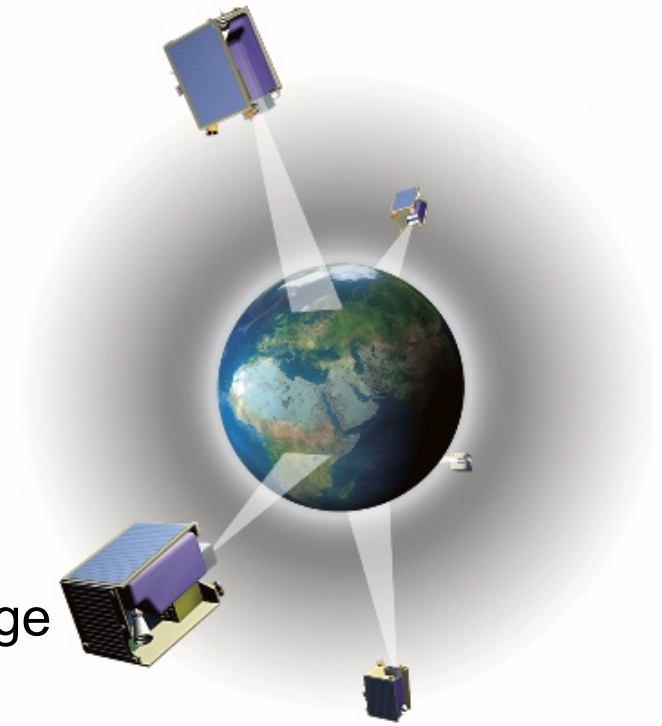




# RapidEye Overview

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- The five-satellite RapidEye commercial EO constellation was launched on Aug. 29, 2008
- The RapidEye System can collect imagery in five spectral bands
  - ◆ Blue, Green, Red, Near Infrared, Red-Edge
- Ground sampling distance: 6.5 m



# RapidEye

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Image is an Ortho  
LEVEL 3B of  
Griffith, New South  
Wales, Australia /  
Imaged by TROCHIA  
(RapidEye 3) (25 km  
x 25 km )  
Acquisition Date:  
Dec 25, 2008





# RapidEye

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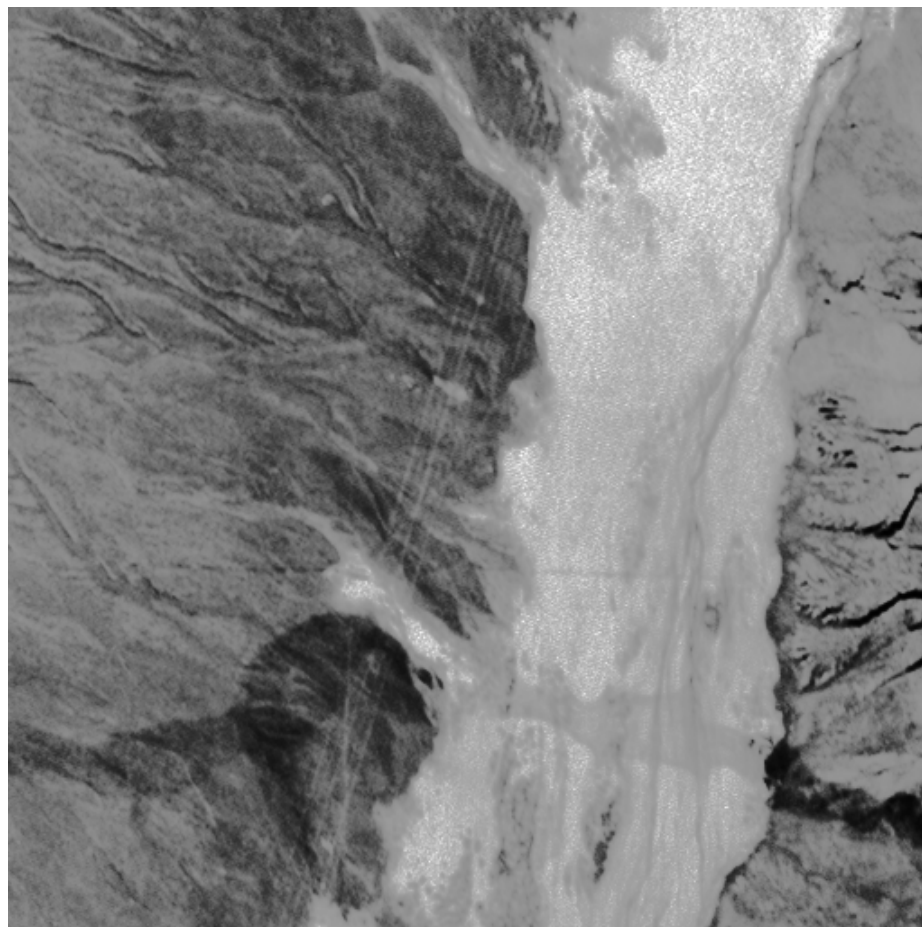
Image is an  
Ortho LEVEL 3B  
of Griffith, New  
South Wales,  
Australia /  
Imaged by  
TROCHIA  
(RapidEye 3)  
(Image Subset )  
Acquisition Date:  
Dec 25, 2008



# RapidEye QA/QC

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- ◆ Striping after passing bright target (RE 1)

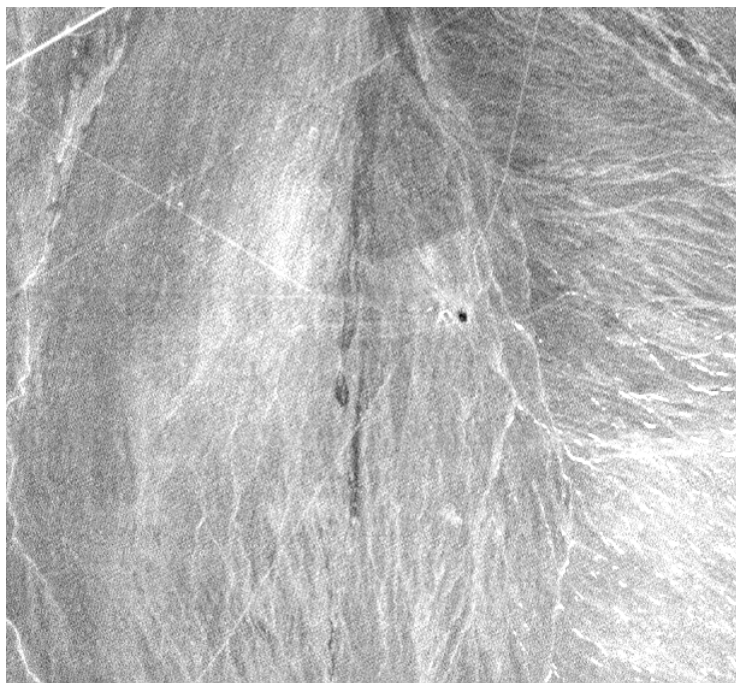




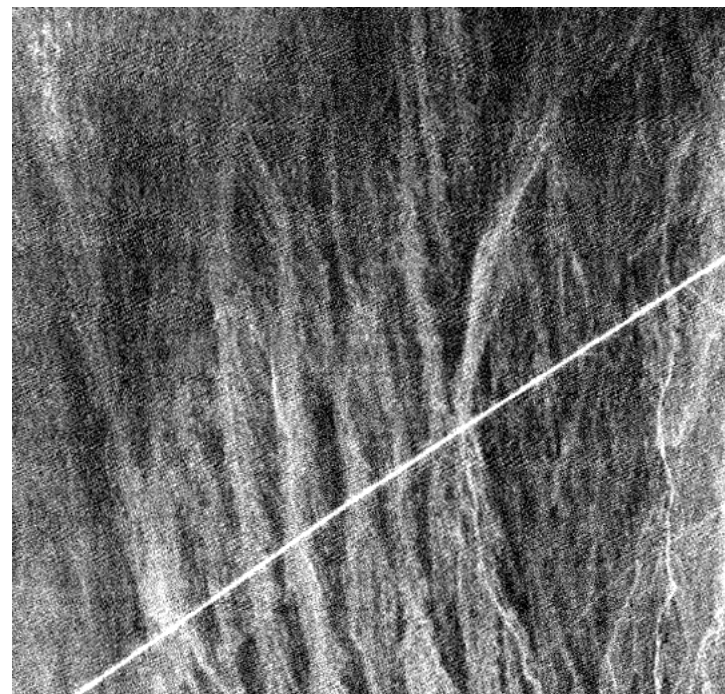
# RapidEye QA/QC

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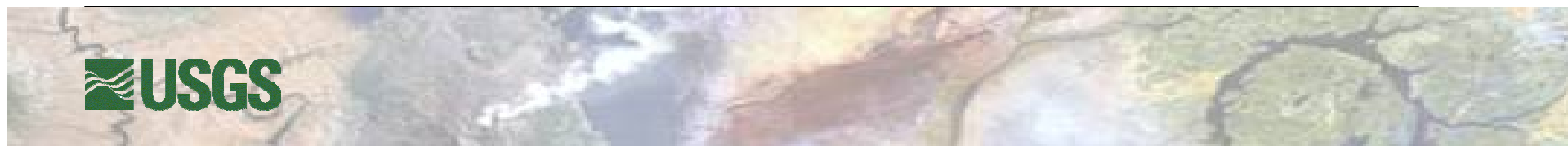
- ◆ Example of Noise



RE 5 Band 1



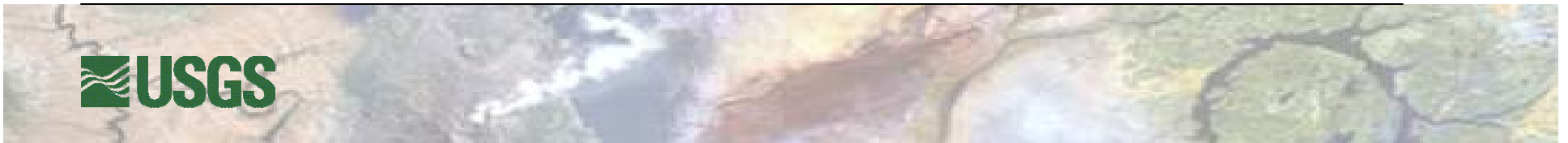
RE 3 Band 1



# RapidEye 3 (I2I) - Australia

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- Since there is no precise ground controls available over Australia, the Landsat data (L1T) is used as reference which are registered to GLS 2000 data (accuracy ~ 20m RMSEr)
- Landsat L1T was created by resampling the 15 m Pan band to 5 m to match the RapidEye data
  - ◆ The resampled L1T data registered to less than tenth of a pixel from the GLS
  - ◆ SRTM DEM
- RapidEye B5 data is used for Image to Image assessment
- Comparing with L1T (GLS 2000), the RapidEye data showed a mean of 35.2 m in the line direction and 18.7 m in the sample direction



# RapidEye 3 (I2I) - Australia

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- The Level 3A (precision & terrain corrected) RapidEye product shows about 40 m RMSEr
  - ◆ Since the GLS products are accurate to ~20 m RMSEr, the inferred RMSEr accuracy of the RapidEye is about 34.6 m
  - ◆ This is not necessarily the accuracy of the RapidEye product as the GLS may not be exactly accurate to 20 m for this particular region

173 points used to calculate statistics	Pixels		Meters	
	Line	Sample	Line	Sample
Mean	-7.05	3.76	-35.2	18.7
Standard Deviation	0.53	0.66	2.6	3.3
RMSE	7.07	3.82	35.3	19.1

# RapidEye R2 (I2I) – RVPN

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- DOQ (resolution 1 m) with an accuracy of ~6 m is resampled to 5 m to match the resolution of the RapidEye B5 data
- Image to Image analysis performed on 12 precision terrain corrected RapidEye scenes
  - ◆ RapidEye 3A products have 25x25 km scene extent
- RapidEye B5 data was used for Image to Image assessment with DOQ
  - ◆ Each scene was compared against DOQ
  - ◆ The mosaic of 12 scenes (created in ENVI) was compared against DOQ
- Individual scene results and the mosaic scene results were consistent
- The relative RMSEr between RapidEye and DOQ is about 1 pixel (5m)



# RapidEye R2 (I2I) - RVPN

- The Level 3A (precision & terrain corrected) RapidEye product shows about 5 m RMSEr in comparison with DOQ
  - ◆ The relative accuracy of RapidEye is within the expected accuracy of DOQ
- RapidEye Australian data may be accurate if the reference GLS 2000 data is not accurate to its specification of 20m CE90.
  - ◆ Due to unavailability of precise controls outside of CONUS, error (if any) in the RapidEye Australian data cannot be accurately validated.

375 points used to calculate statistics for mosaic scene	Pixels		Meters	
	Line	Sample	Line	Sample
Mean	0.76	0.02	3.8	0.1
Standard Deviation	0.47	0.30	2.35	1.5
RMSE	0.89	0.37	4.45	1.85

# RapidEye 2 (I2I) – RVPN

## Individual Scene summary statistics

IMAGE NAME	Num of Points	MEAN		STD		RMSE	
		LINE	SAMPLE	LINE	SAMPLE	LINE	SAMPLE
2009-03-08T192318_RE2_3A-NAC_710489_35641	103	-0.41	0.53	0.24	0.19	0.47	0.55
2009-03-08T192318_RE2_3A-NAC_710490_35641	122	-0.26	0.18	0.38	0.21	0.46	0.28
2009-03-08T192318_RE2_3A-NAC_710491_35641	201	1.36	-0.04	0.31	0.21	1.39	0.21
2009-03-08T192318_RE2_3A-NAC_710492_35641	167	-0.29	-0.39	0.52	0.25	0.6	0.47
2009-03-08T192318_RE2_3A-NAC_710493_35641	179	1.14	0.34	0.21	0.23	1.16	0.42
2009-03-08T192318_RE2_3A-NAC_710494_35641	136	0.69	-0.66	0.21	0.37	0.73	0.75
2009-03-08T192318_RE2_3A-NAC_710495_35641	249	0.94	0.37	0.33	0.18	1.00	0.41
2009-03-08T192318_RE2_3A-NAC_710496_35641	151	0.11	-0.25	0.10	0.17	0.15	0.31
2009-03-08T192318_RE2_3A-NAC_710497_35641	225	0.43	0.03	0.24	0.15	0.5	0.16
2009-03-08T192318_RE2_3A-NAC_710498_35641	154	1.01	-0.09	0.18	0.16	1.03	0.18
2009-03-08T192318_RE2_3A-NAC_710499_35641	180	0.75	-0.36	0.46	0.23	0.88	0.42
2009-03-08T192318_RE2_3A-NAC_710500_35641	218	0.75	0.17	0.18	0.28	0.78	0.33



# RapidEye (I2I) – RVPN mosaic

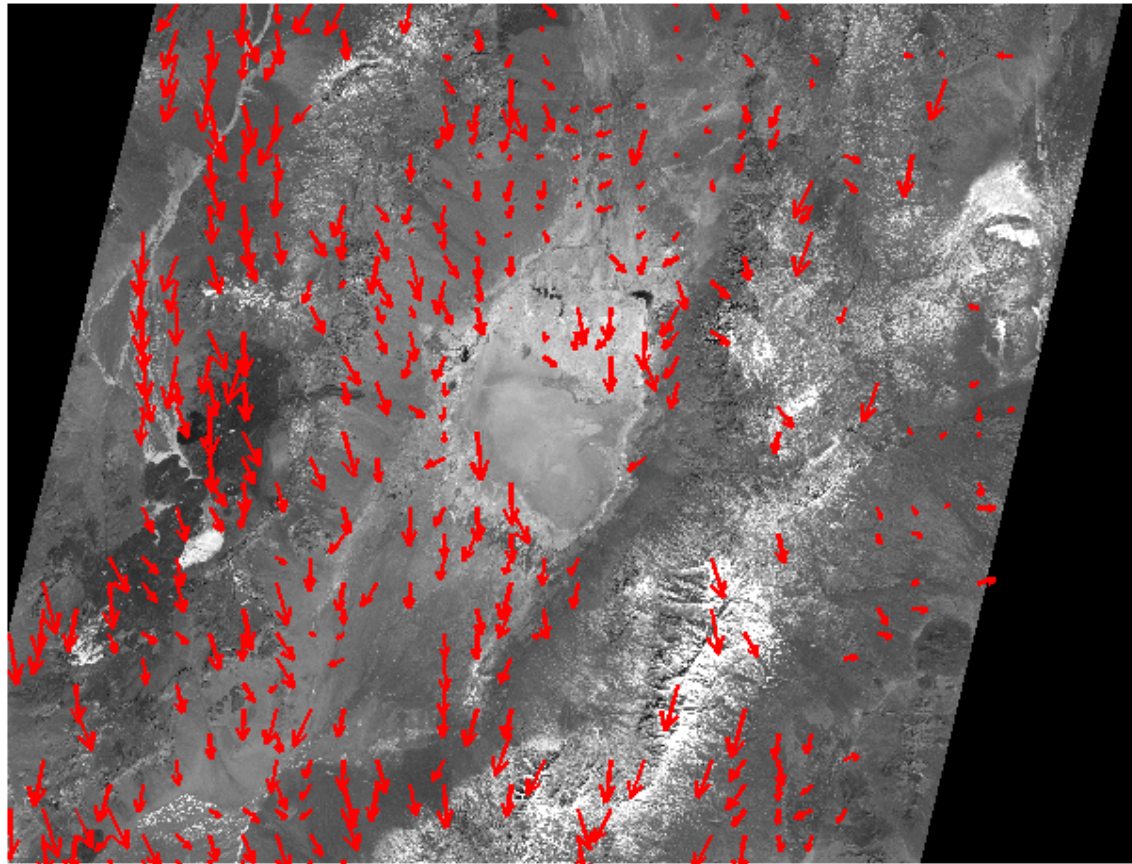
## Vector scale 1:500

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Image to Image comparison

Vector Scale Factor 1 : 500

LINE



SAMPLE

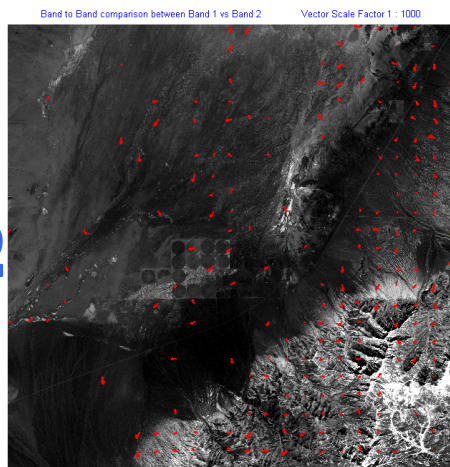


# RapidEye (B2B) – RVPN

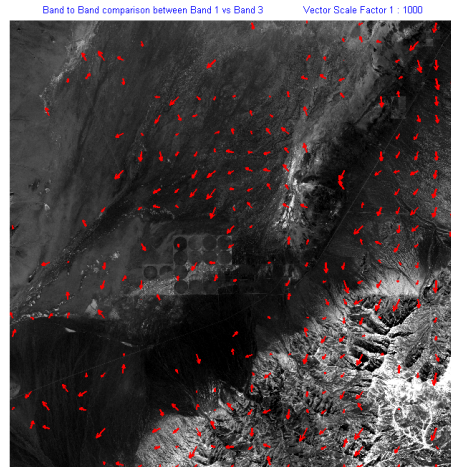
## Vector Scale 1:1000

**B1 - B2**

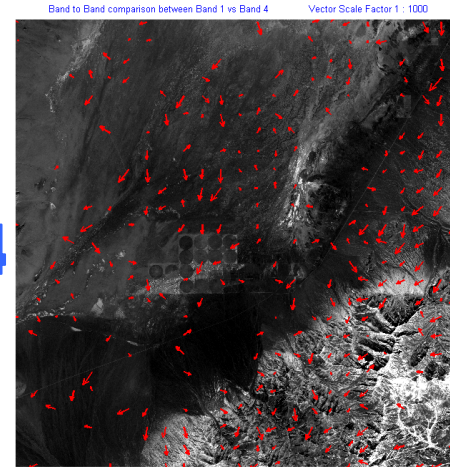
**LINE**



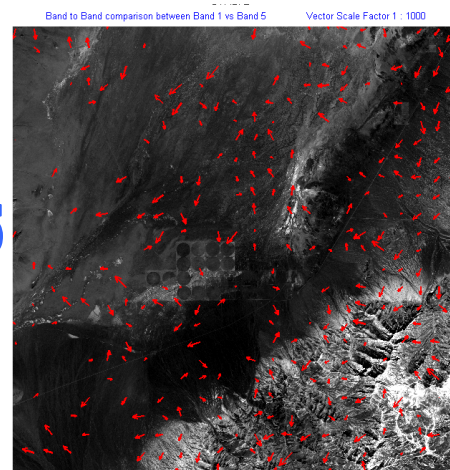
**B1 - B3**



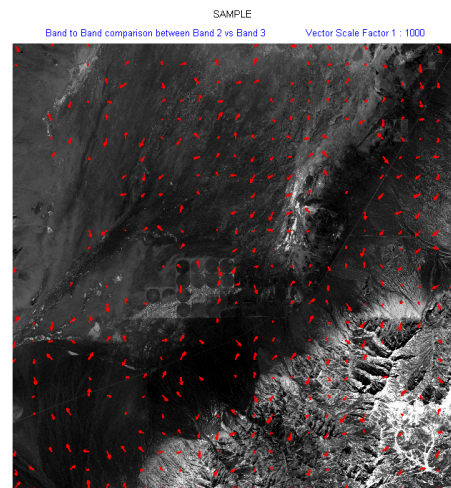
**B1 - B4**



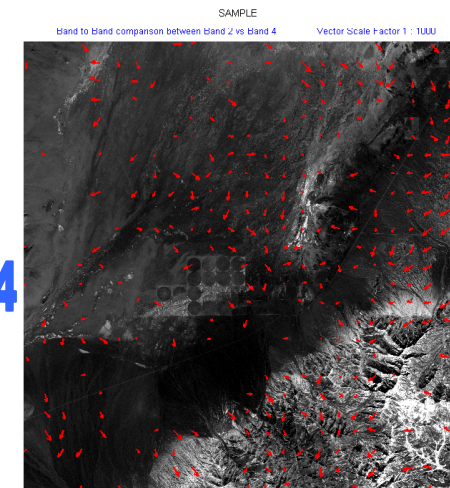
**B1 - B5**



**B2 - B3**



**B2 - B4**



**SAMPLE**





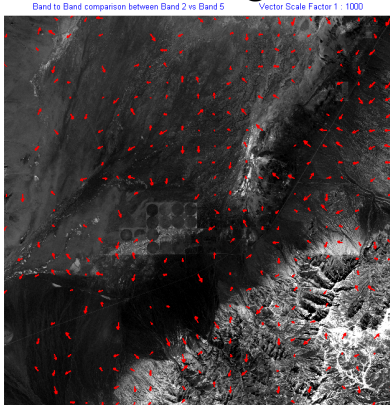
# RapidEye (B2B) Vector Scale 1:1000

**The multi-spectral bands are registered to sub-pixel accuracy**

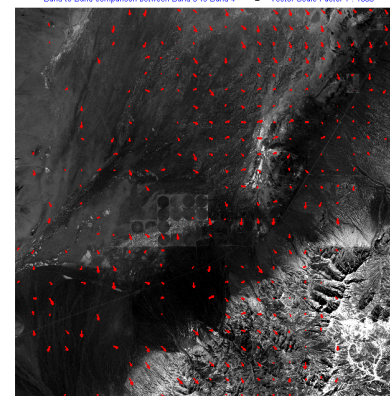
All bands are registered to less than quarter of a 5 m pixel for Australian data

All bands are registered to less than tenth of a 5 m pixel for RVPN data

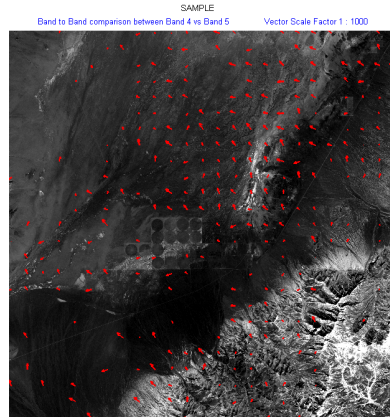
**B2 - B5**



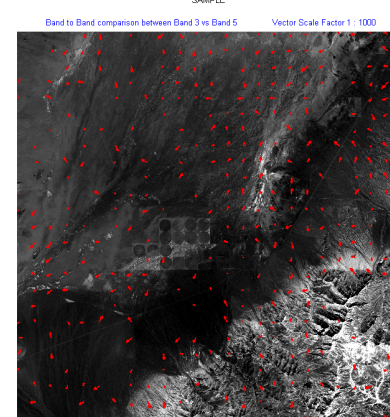
**B3 - B4**



**B3 - B5**



**B4 - B5**



# Summary

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- This year, the USGS EROS Remote Sensing Technologies (RST) team, has completed the data characterizations for WorldView-1, CBERS-2B, SPOT-5, and RapidEye
- Future Analysis: Continued data assessments for RapidEye 1 - 5, GeoEye-1, WorldView-2, THEOS
- The JACIE organizations are committed to assessing the Civil and Commercial sensors of the remote sensing industry. <http://calval.cr.usgs.gov/>
- Imaging campaigns over geometric and radiometric test sites can use one of the Worldwide Test Sites for Sensor Characterization.  
[http://calval.cr.usgs.gov/sites\\_catalog\\_map.php](http://calval.cr.usgs.gov/sites_catalog_map.php)

# Questions?



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# Backup



# Ground Control using Digital Orthophoto Quadrangles (DOQs)

- **DOQs are mosaicked to create a dataset equal to one WRS-2 nominal swath**
  - ◆ Resampled to match Landsat resolution - 1 m DOQs reduced in resolution to match Pan band (15 m for ETM+ and 10 m for ALI)
  - ◆ USGS 1-arc-second DEMs used for ground control height
- **Supersites built from DOQs**
  - ◆ DOQs are designed to meet national mapping accuracy standards of 1:24 k maps, or ~6 m (Inspection with highly accurate GPS surveyed locations showed most DOQs exceeded 6 m)
- **Supersites are georeferenced images derived from high-resolution source**

